Effects of RF Interference

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Introduction

- GPS receivers vulnerable to RF interference
  - Intentional jamming and other interference
  - Can results in degraded navigation, reduces C/N_0
- Interference monitoring and mitigation features must be implemented
  - Military vs. commercial
  - Filtering and antenna implementations
  - Code correction methods

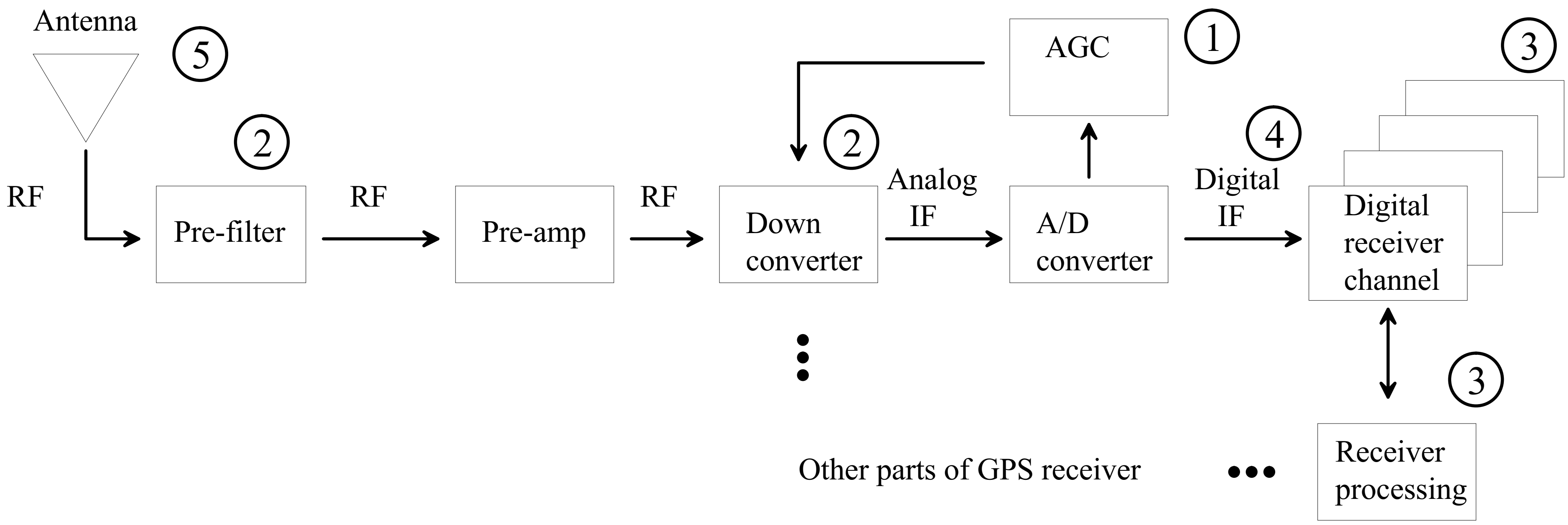
Types and Typical Sources (1/2)

Type	Typical Sources
Wb Gaussian	Intentional noise jammers
Wb phase/ frequency mod.	TV's harmonics or near-band microwave link transmitters
Wb-spread spect.	Int. spread spectrum jammers or near-field of pseudolites
Wb-pulse	Radar

Types and Typical Sources (2/2)

Type	Typical Sources
Nb phase/ frequency mod.	AM stations' harmonics or CB transmitter's harmonics
Nb-swept continuous wave	Int. CW jammers or FM station's harmonics
Nb-continuous wave	Int. CW jammers unmodulated or transmitter's carriers

Locations of antijam techniques



RF Interference Detector ①

- Jamming-to-noise power ratio (J/N) meter
- Provides an instant warning of potential loss of signal integrity
- Implemented at AGC ①
- Based on the knowledge that GPS signals are well below the thermal noise level

Front-end Filtering ②

- Protects receiver from high-powered transmitters that are out of GPS L-band
  - Risk to mix
- Drawback is insertion loss
  - 1 dB insertion loss adds 1 dB to NF and thus decrease tracking threshold 1 dB
- Should have sharp cutoff and deep stopband
  - Hard to implement?
- Downconverter with narrower bandwith

Pulse Interference Suppression

- High energy levels at low duty cycles
- Typical example is a radar transmitter
- Can also overpower the prefilter's ability to reject out-of-band interference
- Solution: limiter using diodes just ahead of the preamp

Code/Carrier Tracking Loop ③

- Enhancement of the code and carrier tracking loops
- Implemented in the digital receiver channels and the receiver processor by narrowing the bandwiths

Narrowband Interfer. Processing ④

- Temporal filtering at the digital IF area for narrowband interferences
- Uses the J/N principle
  - Interfering signal is expected to be above the thermal noise level
- Wideband RF interference cannot be discriminated from thermal noise by temporal filtering

Antenna enhancements ⑤

- Adaptive antenna arrays
- Effective and works for wideband interference
- Null toward the jammer
  - $N - 1$ nulls for an N-element array
  - Low-noise preamplifier per every element
- Canceler
  - Reference antenna has the maximum toward the SVs
  - Sensing antennas have the maxima toward the jammers

A/D Conv. and Code Vulnerability

- Continuous wave interference may be dangerous
  - A/D converter may be captured
  - Disables the receiver to lower jamming levels
- C/A code vulnarable to CW interference
  - Could cause problems because of the leak-through phenomena

Interference reducing factors

- RF interference can only have the full effect if it is in the line of sight of the GPS antenna and obstructed
  - No foliage, buildings ecc.
- In commercial applications interference sources are at ground level while the antenna will be elevated
  - In the aviation applications additionally the body blocks

Analyzing the Effects

- Determine first unjammed C/N_0 for the SV signals
- Then tracking threshold for the receiver
  - Calculate effective C/N_0
- Calculate J/S level at the receiver input
- Finally, the range and power combinations of the RF interference can be calculated

Unjammed C/N_0

$$C/N_0 = S_r + G_a - 10\log(kT_0) - N_f - L \text{ (dB-Hz)}$$

where

S_r	= received signal power (dBw)
G_a	= antenna gain toward SV (dBic)
$10\log(kT_0)$	= thermal noise density (dBw-Hz)
k	= Boltzmann's constant
T_0	= Thermal noise ref. temperature 290 K
N_f	= noise figure
L	= implementation losses

Tracking threshold C/N_0

$$[C/N_0]_{eq} = -10\log\left[10^{-(C/N_0)/10} + \frac{10^{(J/S)/10}}{QR_c}\right] \text{ (dB-Hz)}$$

where

C/N_0 = unjammed C/N_0 in 1-Hz bandwith (dB-Hz)
J/S = jammer-to-signal power ratio (dB)
R_c = GPS PRN code chipping rate (chips/sec)
Q = spread spectrum processing gain adjustment factor

Computing the J/S

$$J/S = 10\log\left[QR_c\left(\frac{1}{10^{[C/N_0]_{eq}/10}} - \frac{1}{10^{(C/N_0)/10}}\right)\right] \text{ (dB)}$$

where

- C/N_0 = unjammed C/N_0 in 1-Hz bandwith (dB-Hz)
- J/S = jammer-to-signal power ratio (dB)
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Exam questions

- Filtering and antenna implementations to suppress RF interference in GPS receivers
- Factors that reduce the effect of the interference (on the signal way, not in the receiver)